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EVALUATION OF A FAN/FILTER SYSTEM TO REDUCE RADON (AND THORON) PROGENY IN UNDERGROUND URANIUM MINES

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EVALUATION OF A FAN/FILTER SYSTEM TO REDUCE RADON (AND THORON) PROGENY IN UNDERGROUND URANIUM MINES

by

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ABSTRACT

The performance of a fan/filter system to reduce radiation levels in an underground uranium mine has been investigated. The fan was installed in a sill drivage where it provided ventilation air to an adjacent production stope. Radiation monitoring stations were located upstream of the fan intake, at the exhaust side of the ventilation ducting in the stope and at a location downstream of the junction of the sill drivage and the mouth of the stope. Measurements were conducted when the fan was operating, with and without the filtering system, and when the fan was off. When the fan was on and the filtering system was in place a reduction in the radon and thoron Working Levels of 10-17% was observed at the stope relative to the intake. Radiation levels at the stope increased substantially when the fan was turned off.

Key words: Radon progeny; Uranium mines; Fans.

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ÉVALUATION D'UN SYSTÈME DE VENTILATION ET DE FILTRATION POUR RÉDUIRE LES PRODUITS DE FILIATION DU RADON (ET DU THORON) DANS DES MINES D'URANIUM SOUTERRAINES

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RÉSUMÉ

Dans le présent rapport, on a évalué le rendement d'un système de ventilation et de filtration visant à réduire le niveau de rayonnement dans une mine d'uranium souterraine. Le ventilateur a été installé dans une galerie souterraine d'où il fournit de l'air à un chantier de production adjacent. Les stations de mesure du rayonnement étaient situées en amont de l'orifice d'entrée d'air du ventilateur, du côté de la sortie d'air des conduits de ventilation dans le chantier d'abattage et en aval du point de jonction de la galerie souterraine et du trou du chantier d'abattage. Les mesures ont été prises lorsque le ventilateur fonctionnait, avec et sans système de filtration, et lorsque le ventilateur était arrêté. Lorsque le ventilateur était en marche et que le système de filtration était en place, on a observé une réduction de 10 à 17 % des niveaux de travail du radon et du thoron dans le chantier d'abattage en ce qui a trait à l'entrée d'air. Les niveaux de rayonnement dans le chantier ont augmenté de façon importante lorsque le ventilateur était fermé.

Mots-clés : produits de filiation du radon, mines d'uranium, ventilateurs.

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CONTENTS

	Page
ABSTRACT	i
RESUME	ii
INTRODUCTION	1
EXPERIMENTAL SITE	1
DESCRIPTION OF THE FAN	2
EXPERIMENTAL PROCEDURE	2
EXPERIMENTAL RESULTS AND DISCUSSION	4
CONCLUSIONS	7
ACKNOWLEDGEMENTS	8
REFERENCES	8

TABLES

No.		
1.	COGEMA fan working schedule	10
2.	Radon progeny and thoron progeny data by grab-sampling	11
3.	Radon progeny and thoron progeny Working Levels by grab-sampling	14
4.	Thoron activity concentration on samples taken with nylon cycones	15
5.	Long-Lived Radioactive Dust (activity concentration) from nylon cyclone samples	16
6.	Long-Lived Radioactive Dust (activity concentration) from cascade impactors	17

FIGURES

1.	Experimental site	18
2.	Radon progeny Working Level data (grab-sampling) versus time for several locations and fan/filter conditions	19
3.	Radon progeny Working Level by continuous monitoring and by grab-sampling (daily shift) versus time for several locations and fan/filter conditions	20
4.	Radon progeny Working Level by continuous monitoring and by grab-sampling (daily shift) versus time for several locations and fan/filter conditions	21
5.	Radon progeny Working Level by continuous monitoring and by grab-sampling (daily shift) versus time for several locations and fan/filter conditions	22
6.	Radon progeny Working Level by continuous monitoring versus time for the exhaust with the fan off	23

INTRODUCTION

Major air pollutants in underground uranium mines include radioactive aerosols, long-lived radionuclides associated with respirable dust, mineral dust in the respirable size range, and diesel particulates.

Radioactive aerosols consist mainly of the short-lived decay products (progeny) of radon and thoron attached to aerosols in the submicron range. In mine working environments, main aerosol contributions are from diesel particulates, mists, oils, and sprays.

A variety of methods have been developed to reduce and control atmospheric pollutants in underground mines. These methods include electrostatic precipitation, wet and dry scrubbing, air recirculation and mechanical filtration, to name but a few methods.

Air filtration is an effective and relatively cheap way of reducing atmospheric pollutants in working environments. In this paper the effect of an exhaust fan and an associated filtering system has been investigated as a means of reducing radon (thoron) progeny, and Long-Lived Radioactive Dust in an underground uranium mine (Stanleigh Mine, Rio Algom Ltd., Elliot Lake, Ont., Canada). The exhaust fan was used to provide ventilation air from a main mine drift to a production stope.

EXPERIMENTAL SITE

The area of the mine selected for the study is shown in Figure 1. It consisted of a section of the sill drivage No. 36021, and the incline No. 36653. Radiation, dust, and meteorological sampling stations were located as follows:

a) nearby a refuge station (No. 36654) in sill drivage (No. 36021);

b) about 12 m from the junction of the sill drivage (No. 36021) and the

incline (No. 36653) into the stope; and

c) approximately 18 m downstream the 36021/36653 junction (see item b).

The fan was installed in the sill drivage about 15 m downstream of the refuge station. The exhaust of the fan was coupled to flexible ventilation ducting leading about 28 m into the incline.

DESCRIPTION OF THE FAN

The fan installed in sill drivage No. 36021 was designed and manufactured by the Compagnie Générale des Matières Nucléaires Établissement de Limoges (COGEMA) and will be referred to henceforth as the COGEMA fan. COGEMA fan model HCIA80/55 was used in the present study.

The COGEMA fan has an air capacity of about 12 m^3 s^{-1} and has been designed with noise reduction features that make it particularly suitable for frequently travelled working areas of the mine.

The COGEMA fan was equipped with a prefilter (AR 100 filtering agent) and a filter model SOREIS No. FCB 100 (thickness 15 mm).

EXPERIMENTAL PROCEDURE

The following measurements were carried out in the sampling stations selected:

A. METEOROLOGICAL VARIABLES

Meteorological data such as air temperature, air moisture content, barometric pressure and airflow (by anemometry) were obtained using grab-sampling techniques and conventional instrumentation.

B. DUST

Dust concentration was measured by means of nylon cyclone dust samplers. Dust size distribution was estimated by means of cascade impactors. Dust measurements are described in detail elsewhere (1).

C. RADIOACTIVITY

The following radiation variables were monitored:

a) radon progeny concentration such as radon progeny Working Level, WL(Rn), [^{218}Po], [^{214}Pb], and [^{214}Bi]. (Square brackets are used to indicate activity concentration.);

b) thoron progeny Working Level, WL(Tn);

c) thoron progeny on nylon cyclone and cascade impactor dust samples; and

d) Long-Lived Radioactive Dust (LLRD), i.e., long-lived radionuclides associated with respirable mineral dust, in nylon cyclone and cascade impactor dust samples.

Radon progeny concentrations were determined by the Thomas-Tsivoglou method (2), the Kusnetz method (3), and by means of radon progeny/thoron progeny continuous monitoring systems, models RGA-400, manufactured by EDA Instruments (Toronto, Canada), and α-PRISM, manufactured by α-NUCLEAR (Toronto, Canada).

Thoron progeny Working Levels, WL(Tn), were determined by grab-sampling using the Rock method (4).

Long-lived radionuclide activity was estimated by gross α-particle counting. Thoron progeny activity on nylon cyclone and cascade impactor samples were also measured by gross α-particle counting.

Measurements were conducted with the fan on and off. Furthermore, the fan was operated with and without the pre-filter and filter, and hereafter referred to as the filtering system. The reason for this experimental procedure was threefold:

a) To determine the effect of the fan on radioactivity levels when the fan was off as opposed to the situation where the fan was operated without the filtering system;

b) To investigate the filtration characteristics, and removal efficiency of

the fan for radon progeny, thoron progeny and Long-Lived Radioactive Dust when the fan was operated with the filtering system in place; and

c) to study plate-out effects on the fan blades when the fan was operated without the filtering system.

The duration of the underground measurements was 9 days, and the schedule indicated in Table 1 was followed for measurement purposes.

EXPERIMENTAL RESULTS AND DISCUSSION

The experimental data have been summarized in Tables 2 to 6 and Figures 2 to 6.

Table 2 and Figure 2 show grab-sampling data taken at the intake, exhaust and sill drift during the regular work-day shift. Daily average values for the radon and thoron progeny Working Levels, and the ratio WL(Tn)/WL(Rn), are shown in Table 3.

Examination of Tables 2 and 3 show the following interesting features (see also Figure 2):

a) WL(Rn) and WL(Tn) were on average slightly higher at the sill drift than at the intake;

b) WL(Rn) and WL(Tn) were higher at the exhaust than at the intake when the fan was off. This is to be expected because of lack of ventilation at the exhaust;

c) when the fan was on and the filters in place, WL(Rn) and WL(Tn) were slightly lower (~10%) at the exhaust than at the intake. This difference can be ascribed to the effect of the filter on the radon and thoron progenies. It also shows that the efficiency of the filter in removing the short-lived decay products of radon and thoron was rather low and not particularly designed for this type of operations;

d) the daily average values for the 'disequilibrium' ratios $[^{214}Pb]/[^{218}Po]$

and $[^{214}Bi]/[^{218}Po]$ for the intake and the sill drift were not significantly different: (0.46, 0.29) to (0.65, 0.47) for the intake, and (0.46, 0.23) to (0.57, 0.40) for the sill drift. (Square brackets are used to indicate activity concentration. The values in round brackets separated by a comma indicate the ratios $[^{214}Pb]/[^{218}Po]$ and $[^{214}Bi]/^{218}Po]$, respectively.

For the exhaust, the disequilibrium ratios were dependent on whether the fan was operated or was turned off. As predicted by theory (5), these ratios were lower when the fan was operating than when the fan was off. It should be noted that the disequilibrium ratios are a measure of the age of mine air, i.e., air residence time. A low value for these ratios indicate young mine air conditions corresponding to a high ventilation rate. The converse is equally true. The highest values measured at the exhaust under no air flow conditions were $[^{214}Pb]/[^{218}Po] = 0.75$ and $[^{214}Bi]/[^{218}Po] = 0.58$, whereas the lowest average values were 0.46 and 0.28, respectively.

e) At the exhaust, the ratio WL(Tn)/WL(Rn) increased substantially when the fan was operating as compared with the case where the fan was off, the converse being equally true. Although to a lesser degree, the same held true at the intake. At the sill drift the situation was, however, somewhat more complicated because conditions at this location are affected by conditions at the intake and the exhaust. Table 2, and to a lesser extent, Table 3, show the effect of the fan on the ratio WL(Tn)/WL(Rn).

As discussed elsewhere (5), the ratio WL(Tn)/WL(Rn) is a good indicator of airflow conditions in an underground uranium mine. The experimental data obtained at the exhaust, are therefore, qualitatively consistent with theoretical predictions. The data at the intake are also to be expected because of the high air flow rate of the fan that creates a noticeable increase in airflow conditions in the area near the fan where the intake

sampling location was situated.

f) Although a decrease in WL(Rn), and sometimes WL(Tn), was observed when the fan was operated (with and without the filter system), losses by plate-out on the fan blades could not be substantiated because the effect was also evident at the intake, and hence, before the air stream entered the fan.

g) The ratio WL(Tn)/WL(Rn) was in the range 0.15 to 0.7, but most of the values were less than 0.4. This is a value significantly lower than that measured in other uranium mines in the Elliot Lake area. Since the rock formation and the strata characteristics are quite similar to the other mines in the area, the low value for the above ratio seems to suggest a lower gram ratio $^{232}Th/^{238}U$.

Figures 3 to 6 show WL(Rn) versus time at the intake, exhaust and sill drift as measured by several radon progeny continuous monitoring systems, and also by grab-sampling. These Figures show:

a) Good agreement between grab-sampling and continuous monitoring;

b) WL(Rn) is 'modulated' at the three locations by substantial increases between 6-7 h and 18-20 h caused by the central blasting during which ventilation fans were turned off. Radiation levels decreased again back to 'normal' when ventilation fan operation was reestablished;

c) As expected, turning the fan off caused a sharp increase in WL(Rn) at the exhaust. The converse was equally true;

d) WL(Rn) at the intake and the sill drift was also somewhat affected by the operation of the fan. The reason for this is the large volume of air drawn by the fan at the intake location which affects conditions at the sampling location. Furthermore, conditions at the intake and exhaust affect conditions at the sill drift; and

e) Items c) and d) agree with data, and discussion, of Tables 2 and 3 and Figure 2.

Table 4 shows the thoron progeny α-particle activity concentration measured on samples taken with nylon cyclones. The data in this Table show that a reduction in thoron progeny concentration is brought about by the operation of the fan with the filters in place. The average reduction was about 17% (10.1% for June 17, 25.5% for June 18, and 15.7% for June 19).

The reduction in thoron progeny concentration measured in samples taken with the cascade impactor was about 14%.

Table 4 also shows that the thoron progeny concentration at the exhaust and the sill drift when the fan was on and the filters in place was essentially the same.

Tables 5 and 6 present Long-Lived Radioactive Dust (LLRD) data (activity concentration) measured with nylon cyclones (Table 5) and cascade impactors (Table 6). Two sets of data are shown, namely corrected, and non-corrected, for 'background'.

Long-Lived Radioactive Dust is associated with mineral dust in the respirable range. Unfortunately, little mineral dust was generated in the nearby production stopes during the COGEMA fan testing period. As a consequence, very little long-lived radionuclide activity was collected on the filters. Negative values for the corrected LLRD activity concentration reflect the poor statistics of counting. It is, therefore, not possible to draw any conclusion regarding the efficiency of the filter system for LLRD from cascade impactor data or nylon cyclone data.

CONCLUSIONS

From the data examined thus far, the following main conclusions can be drawn:

1. When the fan was operating and the filters were in place, WL(Rn) and WL(Tn) were lower (10-17%) at the exhaust than at the intake. When the

fan was off, the converse was equally true;

2. At the exhaust, the radon progeny disequilibrium ratios and the ratio WL(Tn)/WL(Rn) depended on whether the fan was on or off in accordance with theoretical (qualitative) predictions;
3. Because of low mineral dust concentrations in the area where the fan was located, and hence poor statistics of counting, a reduction in Long-Lived Radioactive Dust attributed to the fan could not be ascertained.

In summary, and as expected, radiation levels at the exhaust were lower during the operation of the fan. A reduction in WL(Rn) and WL(Tn) at the exhaust, as compared with the intake, of less than 20% was brought about by the operation of the fan.

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Table 1 - COGEMA fan working schedule

Date	Fan	Filter System	Remarks
June 15/87	On	No	-
June 16/87	Off	No	Fan off at 9:20
June 17/87*	On	Yes	
June 18/87	Off/on	Yes	Fan off at 9:04; fan on at 9:13; fan off at 14:00
June 19/87	On/off	Yes	Fan on at 11:24; fan off at 14:13
June 20/87	Off	Yes	-
June 21/87	Off	Yes	-
June 22/87	Off	Yes	-
June 23/87	On/off	Yes	Fan on at 8:55; fan off at 13:20

*Fan automatically shut-off for blasting from 16:00 to 17:52 (June 17), and from 3:00 to 5:50 (June 18).

Table 2 - Radon progeny and thoron progeny data by grab-sampling

Date	Time	Location	$[^{218}Po]$ $pCiL^{-1}$	$[^{214}Pb]$ $pCiL^{-1}$	$[^{214}Bi]$ $pCiL^{-1}$	$\frac{[^{214}Pb]}{[^{218}Po]}$	$\frac{[^{214}Bi]}{[^{218}Po]}$	WL(Rn)	WL(Tn)	$\frac{WL(Tn)}{WL(Rn)}$	Remarks
June 15/87	10:20	Intake	49.3	31.3	21.9	0.634	0.444	0.291	0.062	0.212	
	11:00	"	55.6	35.4	29.6	0.636	0.532	0.347	0.068	0.197	
	11:40	"	50.8	34.8	22.9	0.685	0.451	0.315	0.070	0.222	Fan on, no filters
	12:20	"	38.2	24.8	21.2	0.649	0.555	0.245	0.065	0.263	
	13:00	"	34.6	22.36	15.6	0.646	0.451	0.207	0.069	0.332	
	13:40	"	33.6	21.21	14.08	0.631	0.419	0.195	0.065	0.335	
June 16/87	9:00	Intake	47.1	23.78	14.66	0.505	0.311	0.224	0.082	0.365	Fan on, no filters
	10:00	"	39.88	20.67	13.32	0.518	0.334	0.196	0.076	0.390	
	10:40	"	39.22	20.61	12.82	0.525	0.327	0.193	0.073	0.379	
	11:20	"	32.8	16.57	10.49	0.505	0.319	0.157	0.069	0.438	Fan off, no filters
	12:00	"	28.1	14.67	8.22	0.522	0.292	0.134	0.057	0.426	
	12:40	"	26.3	14.6	11.4	0.555	0.433	0.144	0.050	0.346	
	13:20	"	29.1	14.1	8.16	0.485	0.280	0.132	0.059	0.448	
June 17/87	9:20	Intake	43.0	21.6	10.39	0.502	0.241	0.193	0.073	0.380	Fan off, filters in place
	10:00	"	39.8	16.8	5.8	0.422	0.146	0.148	0.047	0.319	
	10:40	"	34.9	14.8	6.13	0.424	0.176	0.134	0.058	0.433	
	11:20	"	21.77	10.4	11.97	0.477	0.549	0.120	0.051	0.425	Fan on, filters in place
	12:00	"	26.3	11.55	7.44	0.439	0.283	0.114	0.057	0.498	
	12:40	"	29.5	14.04	8.19	0.475	0.278	0.132	0.051	0.389	
	13:20	"	28.19	13.6	9.66	0.482	0.343	0.134	0.066	0.493	
June 18/87	9:21	Intake	33.5	27.5	24.7	0.821	0.737	0.267	0.080	0.301	
	10:00	"	29.6	20.6	17.4	0.696	0.587	0.201	0.074	0.371	
	10:40	"	29.2	15.8	7.41	0.541	0.254	0.138	0.061	0.439	
	11:20	"	-	-	-	-	-	0.126	0.061	0.482	Fan on, filters in place
	12:00	"	22.1	12.2	10.2	0.552	0.461	0.123	0.061	0.494	
	12:40	"	36.8	17.19	3.76	0.467	0.102	0.139	0.052	0.376	
	13:00	"	32.19	15.6	7.25	0.484	0.225	0.140	0.055	0.391	
June 19/87	8:59	Intake	42.9	23.4	14.2	0.545	0.331	0.216	0.084	0.390	
	9:40	"	25.1	14.86	10.05	0.589	0.400	0.139	0.071	0.515	Fan off, filters in place
	10:40	"	33.8	14.6	4.73	0.432	0.139	0.127	0.069	0.548	
	11:20	"	26.6	12.5	6.98	0.470	0.262	0.117	0.061	0.523	
	12:00	"	33.6	15.3	5.25	0.455	0.156	0.132	0.058	0.441	
	12:40	"	29.8	12.8	6.79	0.429	0.228	0.121	0.075	0.623	Fan on, filters in place
	13:20	"	26.1	12.6	8.71	0.482	0.333	0.102	0.072	0.703	

Table 2 cont. overleaf

Table 2 Cont.

Date	Time	Location	$[^{218}Po]$ $pCiL^{-1}$	$[^{214}Pb]$ $pCiL^{-1}$	$[^{214}Bi]$ $pCiL^{-1}$	$\frac{[^{214}Pb]}{[^{218}Po]}$	$\frac{[^{214}Bi]}{[^{218}Po]}$	WL(Rn)	WL(Tn)	$\frac{WL(Tn)}{WL(Rn)}$	Remarks
June 15/87	9:37	Exhaust	90.6	60.6	50.9	0.669	0.562	0.591	0.090	0.153	
	10:20	"	43.0	28.8	28.8	0.669	0.669	0.308	0.070	0.230	
	11:00	"	56.1	34.5	27.1	0.615	0.483	0.334	0.068	0.203	
	11:40	"	48.7	29.8	25.4	0.612	0.522	0.297	0.063	0.213	Fan on, no filters
	12:20	"	61.6	35.5	13.2	0.576	0.214	0.308	0.066	0.221	
	13:00	"	35.9	21.0	15.1	0.585	0.420	0.200	0.065	0.322	
	13:40	"	26.2	18.4	15.6	0.702	0.595	0.180	0.070	0.389	
June 16/87	9:02	Exhaust	41.8	24.6	16.1	0.588	0.385	0.228	0.082	0.357	Fan on, no filters
	10:00	"	46.0	33.6	24.2	0.730	0.526	0.309	0.085	0.276	
	10:40	"	44.5	37.2	33.3	0.836	0.748	0.359	0.082	0.229	
	11:20	"	59.6	41.1	29.1	0.689	0.488	0.379	0.086	0.227	Fan off, no filters
	12:00	"	61.5	46.9	33.2	0.762	0.540	0.426	0.089	0.210	
	12:40	"	50.3	41.0	35.0	0.815	0.696	0.391	0.096	0.246	
	13:20	"	54.2	36.7	24.8	0.677	0.458	0.335	0.069	0.207	
June 17/87	9:00	Exhaust	79.2	56.1	44.9	0.708	0.567	0.534	0.087	0.163	Fan off, filters in place
	10:00	"	30.4	13.9	9.41	0.457	0.309	0.137	0.069	0.501	
	10:40	"	25.7	11.29	9.18	0.439	0.357	0.118	0.059	0.502	
	11:20	"	22.2	12.5	9.43	0.563	0.425	0.122	0.053	0.433	Fan on, filters in place
	12:00	"	27.0	11.8	6.57	0.437	0.243	0.112	0.049	0.436	
	12:40	"	23.7	13.96	8.45	0.589	0.356	0.127	0.053	0.417	
	13:20	"	30.4	14.6	7.35	0.480	0.242	0.133	0.052	0.389	
June 18/87	9:20	Exhaust	36.7	22.8	18.3	0.621	0.499	0.222	0.081	0.365	
	10:00	"	30.8	20.1	14.5	0.652	0.471	0.188	0.063	0.335	
	10:40	"	23.6	12.0	10.0	0.508	0.423	0.123	0.054	0.441	
	11:20	"	23.5	12.1	7.8	0.515	0.332	0.115	0.060	0.518	Fan on, filters in place
	12:00	"	24.1	12.72	8.2	0.528	0.340	0.120	0.052	0.434	
	12:40	"	27.4	11.7	8.1	0.427	0.296	0.118	0.048	0.410	
	13:20	"	27.2	13.3	7.59	0.489	0.279	0.124	0.048	0.385	
June 19/87	9:26	Exhaust	47.5	37.3	27.9	0.816	0.611	0.350	0.074	0.211	
	10:05	"	41.1	27.9	19.4	0.679	0.472	0.260	0.087	0.335	Fan off, filters in place
	10:42	"	27.7	16.9	11.2	0.610	0.404	0.160	0.075	0.469	
	11:26	"	23.6	11.9	7.5	0.504	0.318	0.120	0.061	0.508	
	12:01	"	25.5	9.6	8.5	0.376	0.333	0.110	0.061	0.554	Fan on filters in place
	12:40	"	27.6	13.7	5.3	0.496	0.192	0.120	0.049	0.408	
	13:20	"	25.5	12.2	6.9	0.478	0.271	0.120	0.074	0.617	

Table 2 cont. overleaf

Table 2 Cont.

Date	Time	Location	$[^{218}Po]$ $pCiL^{-1}$	$[^{214}Pb]$ $pCiL^{-1}$	$[^{214}Bi]$ $pCiL^{-1}$	$\frac{[^{214}Pb]}{[^{218}Po]}$	$\frac{[^{214}Bi]}{[^{218}Po]}$	WL(Rn)	WL(Tn)	$\frac{WL(Tn)}{WL(Rn)}$	Remarks
June 15/87	11:00	Sill drift	49.9	30.7	25.4	0.615	0.510	0.310	0.074	0.239	
	11:40	" "	49.6	28.7	25.2	0.578	0.508	0.300	0.072	0.240	
	12:20	" "	53.9	27.7	16.1	0.514	0.298	0.260	0.060	0.231	
	13:00	" "	47.1	21.8	11.0	0.463	0.233	0.210	0.051	0.243	Fan on, no filters
	13:40	" "	39.3	20.9	10.4	0.532	0.264	0.190	0.064	0.337	
June 16/87	9:10	Sill drift	18.3	15.3	22.1	0.836	1.208	0.180	0.061	0.339	Fan on, no filters
	10:00	" "	35.7	21.5	13.9	0.602	0.389	0.200	0.067	0.335	
	10:40	" "	40.6	19.0	14.2	0.468	0.350	0.200	0.094	0.470	
	11:20	" "	22.9	16.0	13.7	0.699	0.598	0.160	0.071	0.441	Fan off, no filters
	12:00	" "	24.1	15.8	10.6	0.656	0.439	0.150	0.073	0.487	
	12:40	" "	38.0	16.7	8.7	0.439	0.229	0.160	0.068	0.425	
	13:20	" "	25.9	14.4	9.7	0.556	0.374	0.140	0.086	0.614	
June 17/87	9:10	Sill drift	46.5	23.1	9.30	0.497	0.200	0.210	0.054	0.257	Fan off, filters in place
	10:00	" "	39.8	16.7	5.03	0.419	0.126	0.150	0.065	0.433	
	10:40	" "	28.6	13.0	7.27	0.454	0.254	0.130	0.053	0.408	
	11:20	" "	31.7	13.3	7.59	0.419	0.239	0.130	0.056	0.431	Fan on, filters in place
	12:00	" "	31.5	12.4	5.68	0.394	0.180	0.120	0.061	0.508	
	12:40	" "	24.9	13.7	9.13	0.550	0.367	0.130	0.079	0.608	
	13:20	" "	29.1	14.2	7.66	0.488	0.263	0.130	0.056	0.431	
June 18/87	9:20	Sill drift						0.220			
	10:00	" "						0.220			
	10:40	" "						0.140			
	11:20	" "						0.140			
	12:00	" "						0.130			Fan on, filters in place
	12:40	" "						0.120			
	13:20	" "						0.150			
June 19/87	9:00	Sill drift						0.270			
	10:00	" "						0.170			
	11:00	" "						0.160	----------		Fan off, filters in place
	12:00	" "						0.150			
	13:00	" "						0.130			Fan on, filters in place

Table 3 - Radon progeny and thoron progeny Working Levels by grab-sampling. (Average values under 'steady-state' conditions.)

Date	Location	$\overline{WL(Rn)}$	$\overline{WL(Tn)}$	$\frac{\overline{WL(Tn)}}{\overline{WL(Rn)}}$	Remarks
June 15/87	Intake	0.267	0.066	0.247	) Fan on;
	Exhaust	0.268	0.067	0.250	) no filters
	Sill drift	0.254	0.064	0.252	)
June 16/87	Intake	0.168	0.066	0.393	) Fan off;
	Exhaust	0.347	0.084	0.242	) no filters
	Sill drift	0.170	0.074	0.435	)
June 17/87	Intake	0.139	0.058	0.417	) Fan on;
	Exhaust	0.125	0.056	0.448	) filters in place
	Sill drift	0.143	0.061	0.426	)
June 18/87	Intake	0.156	0.063	0.404	)Fan on;
	Exhaust	0.144	0.058	0.403	) filters in place
	Sill drift	0.160*	-	-	)
June 19/87	Intake	0.136	0.070	0.515	) Fan off until ~11:20;
	Exhaust	0.177	0.069	0.390	) fan on at ~11:20;
	Sill drift	0.176*	-	-	) filters in place

*Estimated by means of an 'Instant Working Level Meter' Model MIMIL manufactured by CEA (France).

Table 4 - Thoron activity concentration on samples taken with nylon cyclones.

Date	Location	Activity Concentration cpm m^{-3}	Reduction %	Operating Conditions
June 15/87	Intake	107.4		) Fan on,
	Exhaust	105.4	1.9	) no filters
	Sill drift	81.7		)
June 16/87	Intake	46.8		) Fan off,
	Exhaust	55.9	-19.0	) no filters
	Sill drift	51.8		)
June 17/87	Intake	164.8		) Fan on,
	Exhaust	148.1	10.1	) filters in place
	Sill drift	143.0		)
June 18/87	Intake	118.5		) Fan on,
	Exhaust	88.3	25.5	) filters in place
	Sill drift	94.6		)
June 19/87	Intake	204.1		) Fan off until ~11:20;
	Exhaust	172.0	15.7	) fan on at ~11:20;
	Sill drift	169.2		) filters in place

Note: cpm stands for α-particle count rate in counts per minute.

Table 5 - Long-Lived Radioactive Dust (activity concentration) from nylon cyclone samples.

Date	Location	Activity concentration Non-Corr.	Corr.
		cpm m^{-3}	
June 15/87	Intake	0.526	0.018
	Exhaust	0.336	-0.136
	Sill drift	0.435	-0.002
June 16/87	Intake	0.370	-0.007
	Exhaust	0.421	0.048
	Sill drift	0.574	0.154
June 17/87	Intake	0.296	-0.064
	Exhaust	0.240	-0.118
	Sill drift	0.234	0.049
June 18/87	Intake	0.424	0.102
	Exhaust	0.233	-0.088
	Sill drift	0.393	-0.066
June 19/87	Intake	0.560	-0.034
	Exhaust	0.563	-0.008
	Sill drift	0.460	-0.427
June 23/87	Intake	0.366	0.003
	Exhaust	0.319	-0.036
	Sill drift	0.244	-0.190

Note: cpm stands for α-particle count rate in counts per minute.

Table 6 - Long-Lived Radioactive Dust (activity concentration) from cascade impactors.

Date	Location	Activity concentration Non-Corr.	Corr.
		cpm m^{-3}	
June 15/87	Intake	0.983	0.572
	Exhaust	0.736	0.208
June 17/87	Intake	0.587	0.206
	Exhaust	0.351	-0.028
June 23/87	Intake	0.561	0.257
	Exhaust	0.588	-0.025

Note: cpm stands for α-particle count in counts per minute.

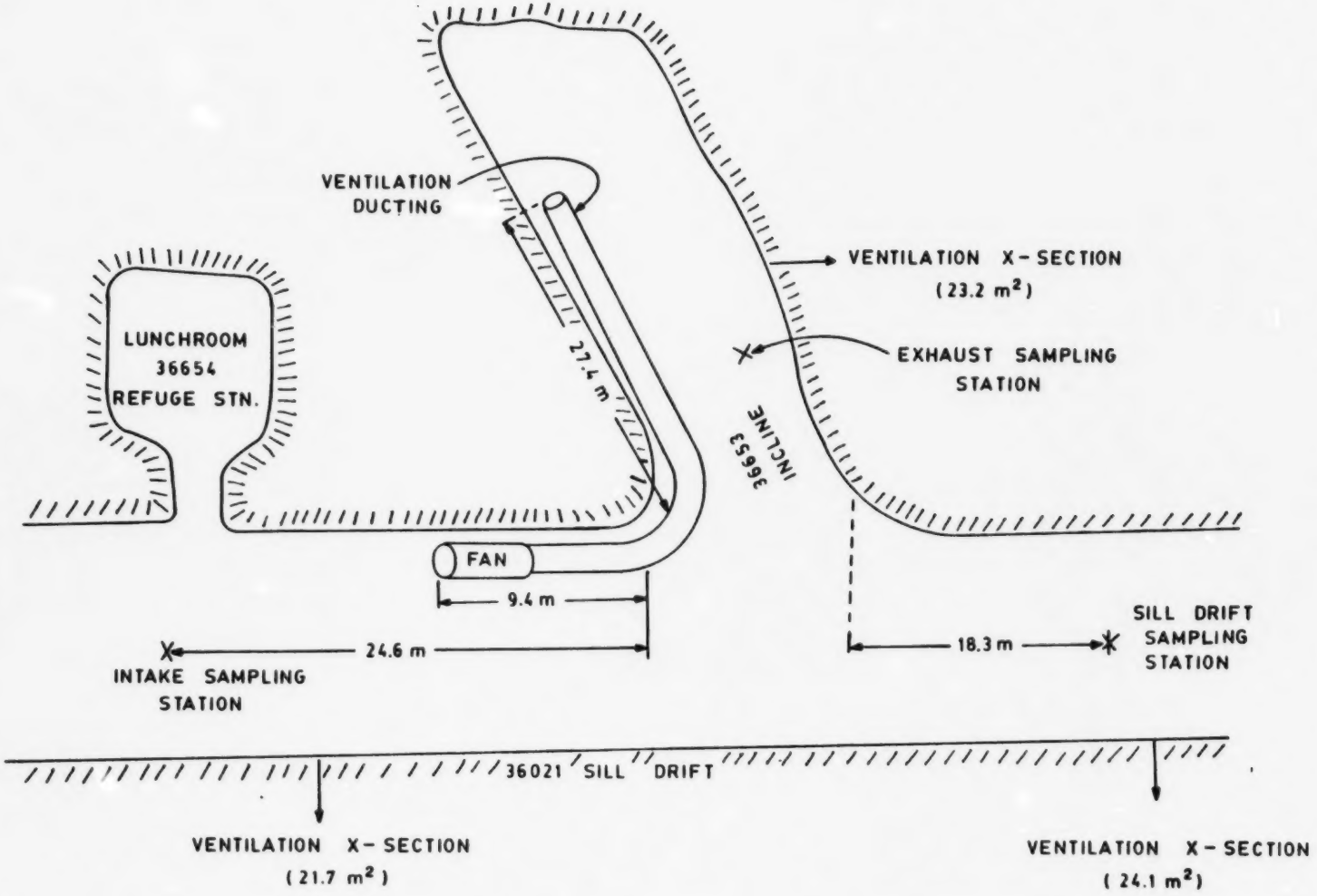

Fig. 1 - Experimental site.

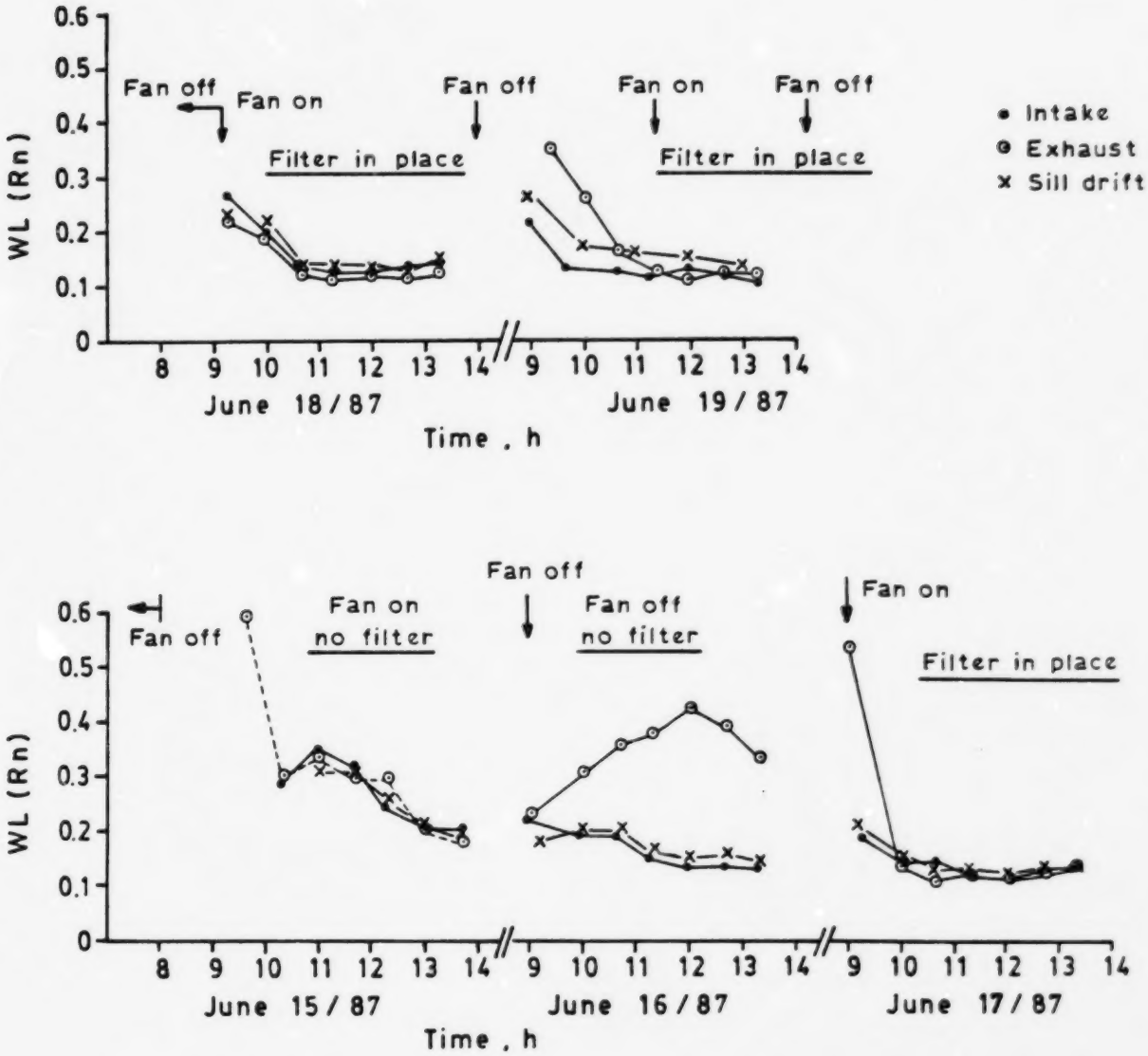

Fig. 2 - Radon progeny Working Level data (grab-sampling) versus time for several locations and fan/filter conditions.

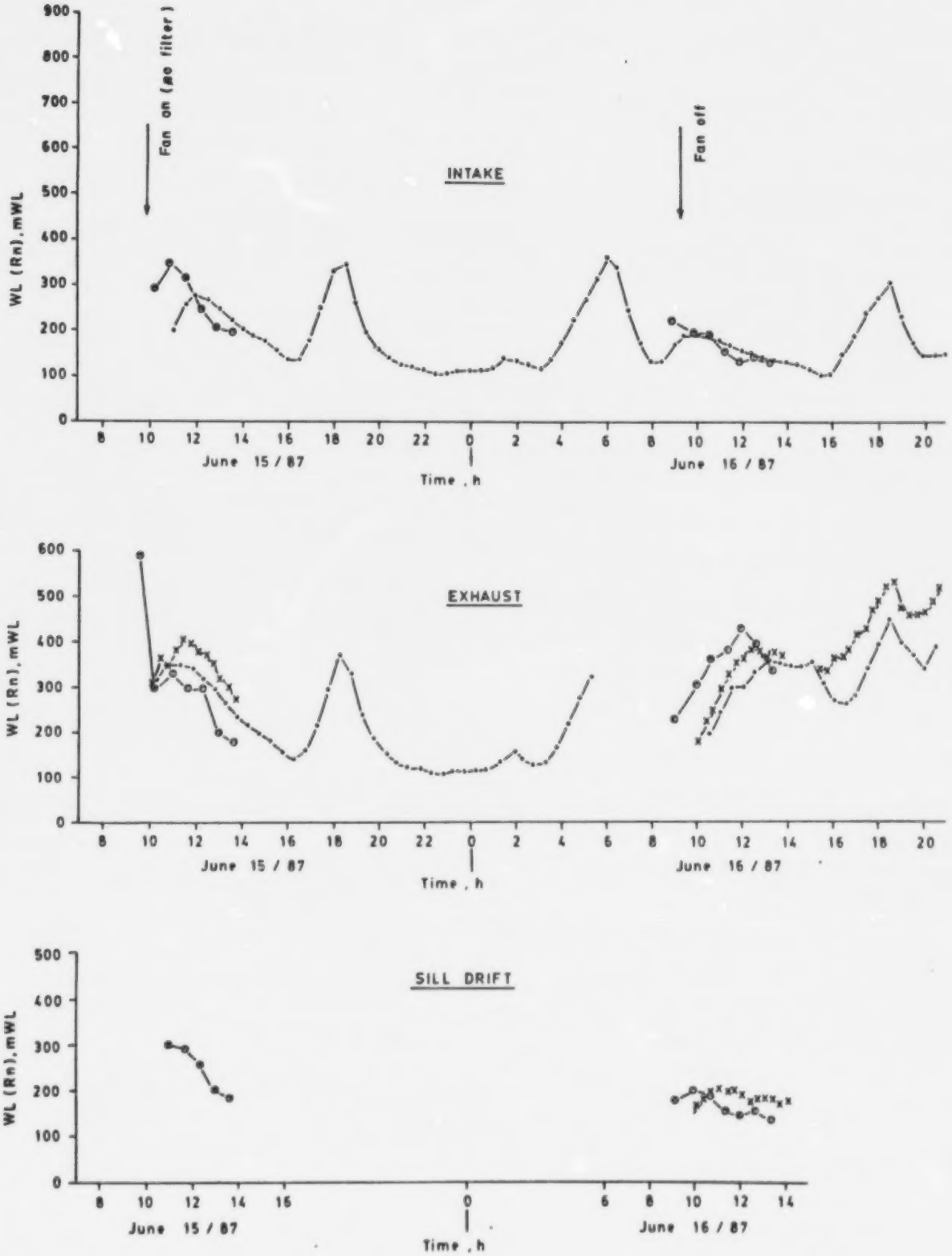

Fig. 3 - Radon progeny Working Level by continuous monitoring and by grab-sampling (daily shift) versus time for several locations and fan/filter conditions.

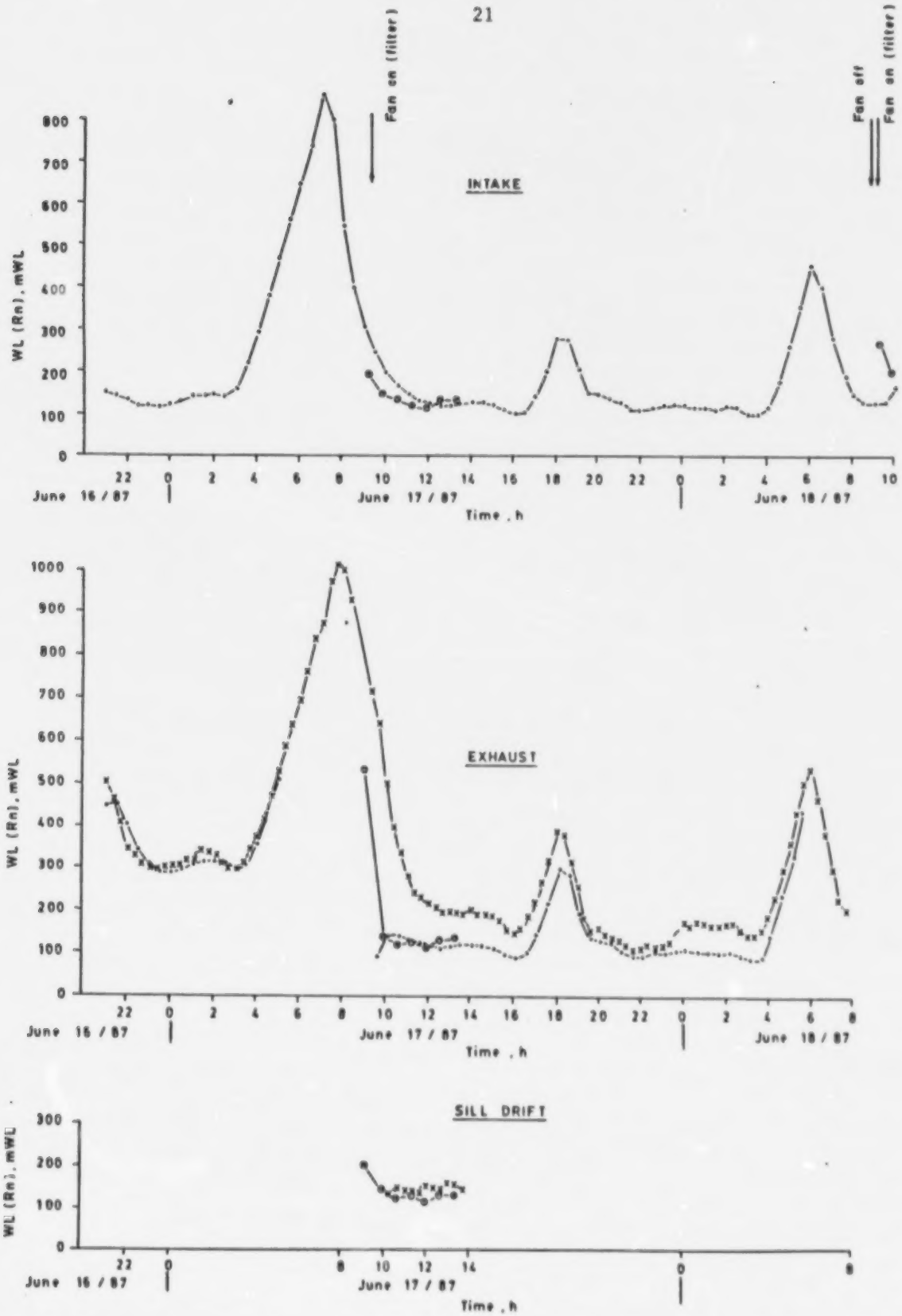

Fig. 4 - Radon progeny Working Level by continuous monitoring and by grab-sampling (daily shift) versus time for several locations and fan/filter conditions.

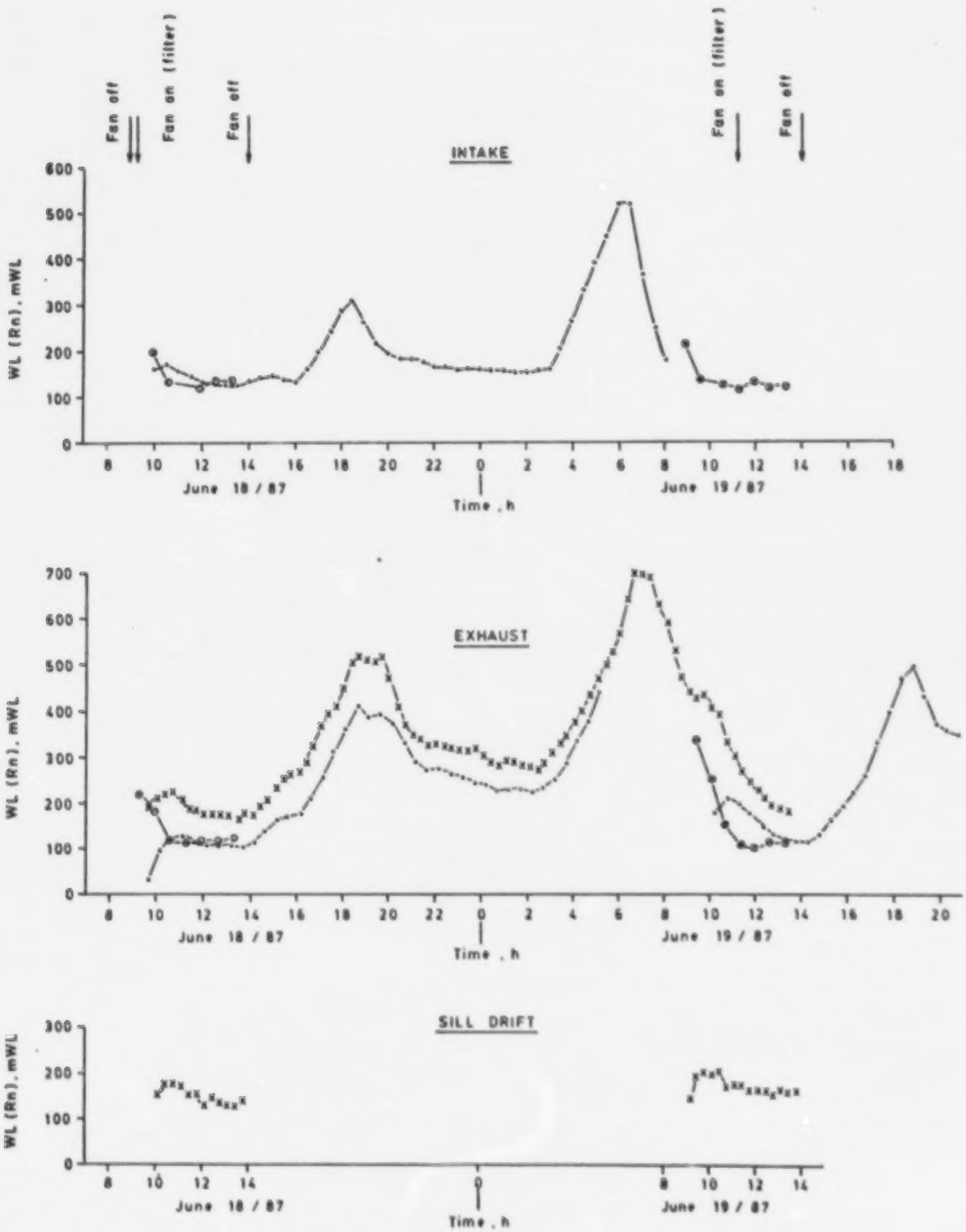

Fig. 5 - Radon progeny Working Level by continuous monitoring and by grab-sampling (daily shift) versus time for several locations and fan/filter conditions.

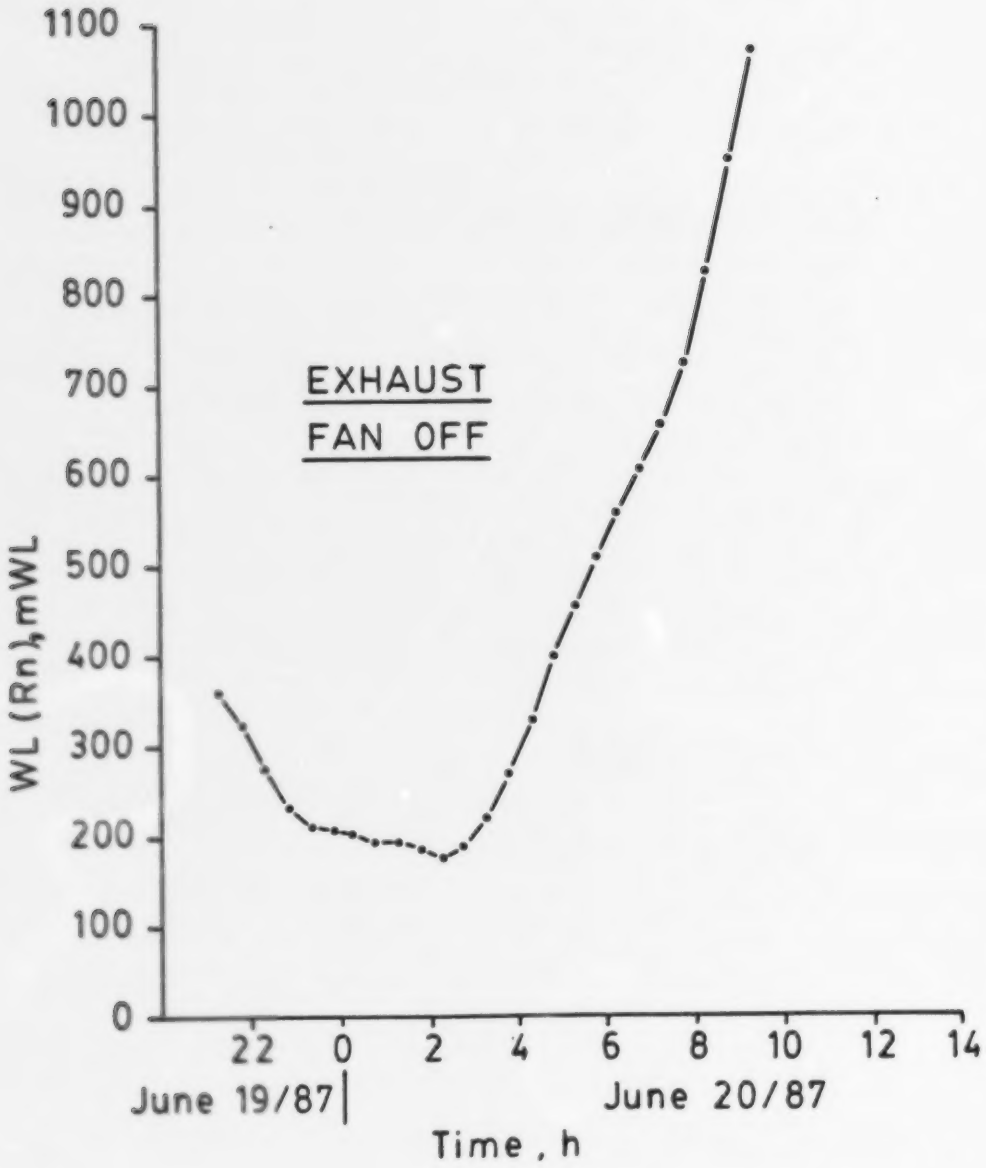

Fig. 6 - Radon progeny Working Level by continuous monitoring versus time for the exhaust with the fan off.